DOCUMENT RESUME

ED 171 908 PS 010 620

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TITLE Intra and Intersensory Haptic Perception: Their Spatial and Perceptual-Motor Correlates.
PUB DATE Apr 79
NOTE 28p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, California, April 8-12, 1979) ; Best copy available

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Early Childhood Education; Elementary School Students; *Haptic Perception; Kindergarten Children; *Perception Tests; Perceptual Development; *Perceptual Motor Coordination; Research; Sensory Integration; Tactual Perception; Visualization; *Visual Perception; Visual Stimuli
IDENTIFIERS *Intersensory Perception; *Intrasensory Perception; Tactile Stimuli

ABSTRACT

This study investigated the relationship between intramodal and intermodal information processing and performance on traditional age appropriate tests of spatial and perceptual-motor abilities. The ability of 65 normal kindergarten, first grade and second grade children to match to either a tactile or a visual standard was assessed with a modified haptic perception box. Each child was seen in six 30-trial sessions. The six sessions, representing six conditions, differed in the modality of the standard, the comparison, the method of presentation and hand(s) used for exploration. After the perceptual assessment, each child was given five standard measures of spatial and perceptual-motor abilities. Among the results, small but stable increases in accuracy and haptic scores with increasing age under both intra- and intermodal conditions were found. Differences were greater between kindergarten and first grade children than between first and second grade children. Children highly proficient in haptic information processing tended to explore the objects completely, as if deliberately mapping the shape. Those less proficient tended to haphazardly explore only a few of the objects' characteristics. Tests of spatial ability were correlated with accuracy and haptic scores of both intra- and intermodal tasks, with intermodal performance being more highly correlated with some tests than intramodal performance. Educational implications and directions for further research are indicated. (Author/RH)

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INTRA AND INTERSENSORY HAPTIC PERCEPTION: THEIR SPATIAL AND PERCEPTUAL-MOTOR CORRELATES

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This research was supported by a Québec Provincial grant awarded to the senior author. It represents one section of a Masters thesis submitted to McGill University by the junior author.

The authors wish to thank Professor Reginald Edwards for his many helpful suggestions.

Paper presented at the annual meeting of the American Educational Research Association, San Francisco, April, 1979.

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Intra and Intersensory Haptic Perception: Their Spatial and Perceptual - Motor Correlates

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ABSTRACT

A review of the literature has suggested that both intramodal and intermodal haptic information processing involves, to varying degrees, the transformation of tactile images into visual spatial representations. For young children, both intramodal and intermodal haptic exploratory behaviors and accuracy were found to be highly correlated with performance on age appropriate tests of spatial and perceptual-motor abilities, with intersensory haptic performance being a better predictor of spatial ability than intrasensory processing. The results are examined in view of the developmental theories of intersensory information processing and the development of spatial ability. Educational implications and directions for future research are discussed.

Research in the psychology of perception has long been directed toward the description of mechanisms underlying visual and auditory processing. By contrast, studies of haptic (active touch) information processing are few and scattered, although the psychological history of such investigations is a long one (Woodworth, 1938).

Within recent years there has been a growth of interest in the nature and development of effective haptic exploratory strategies in the belief that sensory functioning plays a central role in cognitive maturation (Abravanel, 1968; Derevensky, 1978; Piaget & Inhelder, 1956; Zaporozhets, 1965, 1969). As well, theoretical and empirical attention has been focused on the relationship and interdependence among perceptual systems in general and between the visual and haptic systems in particular (Abravanel, 1971; Gibson, 1966; Freides, 1974; Goodnow, 1971; Pick, Pick & Klein, 1967). A considerable body of literature aimed at comparing the relative efficacy of visual and haptic information processing in children both within (intramodal) and across (intermodal)[1] modalities has evolved.

Piaget and Inhelder (1956) in an extensive treatise of haptic perception, intersensory perception and spatial ability viewed the development of perception as a transition from the infantile visual perception of space to its representational construction. The practical sensori-motor activities engaged in by the child during his first two years of life are later transformed and reappear at a symbolic or conceptual level. The symbolic representation of space is a process whereby the child develops an 'internal schema' of the object-as-explored and can then recreate the original percept of the object through mental imagery. It is this gradual internalization process which allows the child to become less stimulus-bound and more of an imaginative thinker.

Piaget and Inhelder (1956) maintained that

> The shape is abstracted from the object by virtue of the actions which the subject performs on it, such as following its contour step by step, surrounding it, traversing it, separating it (p.27).

[1]Intermodal, intersensory and cross modal transfer are used synonymously in a generic sense to refer to tasks in which the subject utilizes information obtained in one sensory system to solve a task in another (eg. haptic-visual, visual-auditory). Intramodal and intrasensory transfer denote an equivalence of information processed totally within one perceptual system (eg. haptic-haptic, visual-visual). (After Pick et. al., 1967).

The importance of sensory-motor activity to their formulation of perceptual growth led Piaget and Inhelder (1956) to pursue a developmental analysis of haptic exploration. In a series of experiments, children age 2-7 years were presented with both familiar objects and cardboard cutouts of geometrical shapes of varying complexities. The stimuli hidden from view by a vertical screen were presented successively to the subjects who were required to manipulate and name each object and then identify it among several comparison objects presented visually. In keeping with Piaget's general theoretical position, it was suggested that the development of intrasensory and intersensory haptic/visual perception of shape could be defined by several ontological sequential stages, ranging from the global haphazard movements of the very young child (age 2;6 - 3;6) to the more refined and systematic explorations of the older child (age 6;6 - 6;7).

Abravanel's (1968) analysis of intersensory patterning in children age 3;4 - 14;2 years included a careful specification of stimulus dimensions and a description of exploratory activities engaged in at different age levels. The results were similar to Piaget & Inhelder's (1956) findings in suggesting that

> the ontogenesis of haptic perception and exploration is from gross performatory action in which palms are used, to fine and articulated perception by means of fingers and fingertips ... At a number of ages, the relation between increased accuracy and exploratory technique was clear in that major increases in accuracy were correlated with the introduction of more mature exploratory forms (Abravanel, 1968, p.49).

The younger child fails to differentiate between the performatory and perceptual functions of the hand. As exploration becomes more active and systematic, the older child is able to engage in several successive encounters with the stimulus object, (Piaget's (1961) notion of decentration) and becomes familiar with all its parts. This familiarity with the various features of the stimulus is followed by its successful identification.

Soviet research on intramodal and cross modal perception has indicated similar age-related changes in exploratory behavior and accuracy of discrimination. In the Russian literature (reviewed by Pick, 1964; and Zaporozhets, 1965, 1969) perception involves a copying of the external world by the perceiving organism. The percept itself is a composite of the feedback stimulation from this mirroring or copying process. Thus motor activity plays a central role in directing and correcting perception. As

the child matures and is instructed, his exploratory strategies become more 'orthoscopic' and he is better able to accurately reflect the environment (Zaporozhets, 1965).

Much of the Soviet experimental literature has been concerned with the documentation of developmental differences in orienting or copying functions of eye and hand movements and their correlation with veridicality of perception. Ginevskaya(reported in Zaporozhets, 1965) had children explore objects haptically and found a gradual progression from the primitive hand movements (pulling, pushing) of children ages $3\frac{1}{2}$-4 years to the more refined tracing explorations of 7 year olds reflecting an attempt to assimilate the specific features of an object. The more complete method of acquaintance at this age is accompanied by a considerable increase in the effectiveness of haptic perception.

Zinchenko and Ruszkaya (reported in Zaporozhets 1961, 1965) directly recorded the eye and hand movements of children 3-6 years of age while they were exploring unfamiliar shapes. They discovered that three year olds focused on the center of the object, failing to explore the entire contour. There was a gradual decrease with age in perceptual centrations such that all parts of the shape were visually or haptically scanned. In addition, the older child paid special attention to the edge of the forms, a location of maximum potential information. Vurpillot's (1968) refined methodological study linking visual exploratory behavior with accuracy lends further support to Zinchenko and Ruzskaya's results.

Early sensory training is a precursor of cognitive and social growth is an integral part of the Soviet motor theory of perception (Pick, 1964; Zaporozhets, 1969). The child must be an active participant in the learning process. The structured training programs focus on the analysis, synthesis, comparison and generalization of stimulus features. Children are trained to attend to those aspects of the stimulus configuration that the Russian experimenters have defined as salient and are encouraged to model specific features of the explored object, thereby providing a better understanding of the environment and facilitating the development of perceptual-motor coordination.

James and Eleanor Gibson (1966; 1969 respectively) also recognized the importance of sensory activity in perceptual development, although they did not consider representational schemas (Piaget & Inhelder, 1956) or feedback from motor acts (Leontiev, 1961) to be the operative factor. They

maintained that organisms actively seek information, invariant over time, which specifies the 'dimensions of difference' or 'distinctive features' in their environment. Perceptual development involves learning to detect these critical variables and shows three gradual trends: 1) an increased specificity of discrimination; 2) an optimization of attention and; 3) an increase in the economy of information pickup (Gibson, 1969). Age-related improvements in perceptual tasks can be attributed to more adequate specification of distinctive features in the environment.

These extensive analyses of ontogenetic differentiation of space at both the perceptual and imaginal levels tend to reflect a close cooperation between visual and haptic activities. As well, empirical investigations of the coding and retention characteristics of the visual and haptic systems suggest a transformation process whereby information processed haptically is translated into a visual memory store (or vice-versa). Since it would appear that the development of intramodal haptic and intermodal visual-haptic perception involves, to varying degrees, the translation of tactile images into spatial representations, the present study attempts to assess the relationship between intra and intermodal information processing and performance on traditional age appropriate tests of spatial and perceptual-motor abilities.

METHOD

Subjects

A total of 65 children enrolled in a middle class school in a suburb of Montreal served as subjects. All were English speaking and were considered of normal intelligence by their teachers. The sample was comprised of 20 kindergarten children (age range 65-74 months, $\bar{X}$ = 70 months), 22 first grade children (age range 77-88 months, $\bar{X}$ = 82 months) and 23 second grade children (age range 89-100 months, $\bar{X}$ = 97 months).

Materials

The test apparatus consisted of a wooden box (the haptic perception box, adapted from Derevensky, 1976) constructed of plywood and painted bright yellow. A board was placed in the middle of the box in order to restrict the child's hand from wandering as well as to ensure that only the designated hand touches each object at any given time. In the center of the box there were two openings covered by felt material with a slit in the middle which

allowed for proper positioning of the child's hand while restricting any visual information about the tactual stimuli. The experimenter's side of the box was open to facilitate placement and removal of stimuli and to permit observation of the child's exploratory activity. A moveable reverse mirror screen (17cm. x 22cm.) was attached to one side of the box at the eye level to the child. A Kodak pocket carousel projector (Auto Focus #30) was placed behind the box, out of the child's view.

(The stimuli used in the present study are reproduced in Appendix A). A green triangle, two blue squares identical in all respects, and a yellow rectangle were used as practice items to determine if the child understood the concept of 'same' and 'different' and to acquaint him with the general procedure of the experiment. The 47 shapes to be used could be grouped into three major categories according to their geometric properties (1) euclidian (2) topological and (3) mixed forms (containing both euclidian and topological characteristics).

The three dimensional shapes used for haptic exploration were made of a smooth textured plastic material (Sansplint - T.M.) and would fit within an 8 x 8 cm. square. Tracings of each shape were photographed and projected on slides as two dimensional white forms on a dark background. Care was taken to ensure that the projected size of these visual forms was equal to that of the haptic forms and that both visual and haptic exploration took place with the stimuli in the same plane and position relative to the subjects. All material had been pilot tested with a small sample of preschool and fourth grade children to ascertain that no floor or ceiling effects would occur.

The Haptic Scoring Sheet (Appendix B), adapted from Derevensky (1976) and based on protocols provided by Laurendeau and Pinard (1970) and Hoop (1971), was used for recording and assessing qualitative differences in haptic activity. It permitted the recording of explorations in four global levels ranging from minimal and haphazard manipulation to complete and systematic activity. Each of the four general levels contained more specific classifications of exploratory movements such that the experimenter could provide an actual description of the child's explorations as well as record his level of exploration. Reliability was assessed by obtaining measures of agreement between three coders who judged each child's haptic explorations according to the categories delineated by the scoring sheet. The agreement between the coders was found to be 89 percent for global levels and 83 percent for exploratory activity within each level.

Experimental Conditions

Throughout the experiment each child was presented with two shapes in a paired comparison format (a standard followed by a comparison)and was required to determine if the comparison shape was the same as or different from the standard. A paired comparison paradigm was used in place of a match-to-sample task (one standard followed by several comparisons) because pilot testing had revealed the young child's inability to process numerous stimuli in a haptic mode. Thirty pairs of shapes were used, each pair representing a single trial. Thirteen pairs of stimuli were identical and seventeen pairs were different. Each child was seen in six 30-trial sessions. The six sessions, representing six conditions (Conditions 1-6) differed as to the modality of the standard, modality of the comparison, method of presentation and hand(s) used for exploration. A summary of the experimental conditions can be found in Table 1.

Insert Table 1 about here

Conditions 1, 2 and 3 involved an intramodal matching task. Both standard and comparison shapes were presented for haptic exploration. Conditions 4, 5, and 6 involved an intermodal matching task. Visual inspection of the standard was followed by haptic exploration of the comparison or vice-versa. The stimulus pairs were presented in a variable order within each condition and the sequence of conditions was randomized. Each child was presented with only one condition per day. There was a 2 day interval imposed between conditions and a two week interval between intramodal and cross modal tasks. The average time to complete each condition was approximately 12 minutes, although the exact time varied with the condition employed and the age of the child.

Procedure

Each child was brought individually into the testing room where he was shown both sides of the haptic perception box and told that he was going to play some games with this 'house'. The experimenter then presented a square and rectangle to the child for visual inspection and queried, "Are these two objects the same or different?" If the child was correct the experimenter responded by saying, "very good". If incorrect she responded "look at them very carefully, are they the same or not the same?" If the

child still failed to correctly indicate that they were different, the experimenter responded, "O.K. Let's try another pair" Two additional pairs of objects (square-square and square-triangle) were presented visually in order to verify that the child understood the concept of'same-different'. Each child then received instructions appropriate to the condition being investigated. All instructions were completed prior to stimulus presentation. A 15 second interval was imposed between trials.

Upon completion of the perception tasks under all conditions each child was administered the following tests selected as measures of a wide range of spatial and perceptual-motor abilities:

a) Block Design Subtest of the Wechsler Intelligence Test for Children-Revised (WISC-R) (Wechsler, 1974).
b) Coloured Progressive Matrices (Revised Order) (Raven, 1956).
c) Spatial Relations Test of the Primary Mental Abilities (PMA) (Thurstone & Thurstone, 1963).
d) Rutgers Drawing Test A (Starr, 1970).
e) Modified Gottschaldt Embedded Figures Test (MacFarlane Smith, 1964; Vernon, 1969).

The order of presentation of these tests was randomized.

RESULTS AND DISCUSSION

The analyses of the child's same-different judgments for each pair of forms were scored 1.0 if correct and 0.0 if incorrect. A total accuracy score (possible range from 0.0 to 30.0) for all individuals under each condition was computed. Haptic perception scores (range 1-4) delineated the level of exploratory movements in each trial under all conditions.

An anlysis of developmental changes in haptic perception and accuracy is presented in Table 2.

Insert Table 2 about here

There are small but stable increases in accuracy and haptic scores with increasing age under both intramodal and intermodal presentation conditions. This is consistent with a large body of experimental literature reflecting developmental trends in intra and intersensory processing. (Abravanel, 1968, 1971, 1972; Birch & Lefford, 1963, 1967; Butter & Zung, 1970; Cronin, 1977; Davidson, Cambardella, Stenerson & Carney, 1974; Gravensky, 1976; Goodnow, 1971; Hoop, 1971; Jackson, 1973; Millar, 1972; Millar & Bryant, 1970; Piaget & Inhelder, 1956; Pick & Pick, 1967; Rudel & Teuber, 1964; Salkind, 1976). An examination of accuracy scores at three

criterion levels (Table 3) and the differential haptic exploratory scores

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Insert Table 3 about here

(Table 4) for Kindergarten, Grade 1 and Grade 2 children suggests a greater

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Insert Table 4 about here

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difference in both accuracy and complexity of haptic strategies between Kindergarten and first grade children than between first and second grade children. A plateau effect may have occurred with a stabilization of both haptic and cross modal abilities at approximately seven years. Other investigators (eg. Abravanel, 1968, 1972; Conners, Schuette & Goldman, 1967; Gliner, 1967; Piaget & Inhelder, 1956) have similarly found consolidation of these processing skills to occur at approximately age 7. It should be noted, however, that the age at which stable responding is achieved must be considered in relation to the differential difficulty of stimulus items used. Dependent upon the reported ease of discriminability of the stimuli in the visual and haptic modes (a methodological problem since little data is available to suggest task equivalence) other research has yielded a plateau effect at earlier ages (eg. Birch & Lefford, 1963) or at later ages (eg. Cronin, 1977).

Observations of haptic activity in this investigation suggested a qualitative difference in the approach to the paired comparison task between younger and older children on the one hand, and between children who are successful and those who are not, on the other. Children highly proficient in haptic information processing tend to explore the objects completely, in a deliberate manner as if mentally mapping the shape, whereas those less proficient generally explore the object haphazardly often focusing on a single aspect and basing responses on a limited number of cues. This age-related transition from arbitrary and superficial exploration to goal-oriented haptic scanning of stimuli and the concomitant increase in accuracy has been reported in several other descriptive analyses of intra and inter-sensory development in children. (Abravanel, 1968; Derevensky, 1978; Hoop, 1971; Piaget & Inhelder, 1956; Zaporzhets, 1965).

An intercorrelation matrix, between age, accuracy, various measures of spatial ability and intra and intermodal perception, is presented in Table 5.

Insert Table 5 about here

The finding of a higher correlation between haptic score and accuracy ($r = .68$) than between age and accuracy ($r = .52$) further reflects the positive relationship between the sophistication of exploratory strategies and correct identification of the item explored. Total haptic accuracy appears to be most highly correlated with the Spatial Relations Subtest of the P.M.A. ($r = .66$) and the Rutgers Test of Perceptual-Motor Abilities ($r = .63$). Examination of the degree of correlation of many of the subtests with intramodal accuracy and haptic scores (Conditions 1-3, Factors 9 and 11) as opposed to intermodal accuracy and haptic scores (Conditions 4-6, Factors 10 and 12) indicates a larger correlation between intermodal performance and scores on the Ravens and the Gottschaldt than between these tests and intramodal performance. This finding tests to suggest that these tests may be better predictors and measures of intersensory abilities than purely haptic skills. The Rutgers which was expected to show a higher correlation with intermodal than intramodal performance, yields high correlations for both groups of conditions that differ very little in magnitude. It is conceivable that the Rutgers which shows a very high correlation with the Spatial Relations Subtest of the P.M.A. ($r = .82$) (a test which also reveals uniformly high correlations with both intra and intermodal performance) is not as pure a measure of intersensory abilities as previously thought.

In summary, tests of spatial ability are correlated with accuracy and haptic scores of both intra and intermodal tasks, with intermodal performance being more highly correlated with some tests than intramodal performance. This finding can be understood in light of the nature of the cross modal matching task. Translation of the haptically perceived image into a visual representation (or vice-versa) is a requirement for successful performance. Indeed, the role of spatial imagery in cross modal tasks has been suggested in the work of Abravanel, (1968) Blank, Altman and Bridger, (1968) and Ford, (1967) but had not been explicitly studied. A more recent study by Salkind, (1976) found a significant correlation between cross modal perception and performance on the Koh's Block Design Test, a test of spatial visualization. He concluded

that the ability to perform on a spatial visualization task is a developmental skill enhanced by input from the haptic modality. The association between intramodal haptic performance and spatial ability was also reported by Derevensky (1976). Although no translation between visual and tactile input is required for judgment of equivalence totally within the haptic system, it is conceivable that visual images are nevertheless being created from haptic cues. This assumption is supported by the frequent observations of the children in this study that they felt the object and 'pictured it in their heads'. Ford (1973) similarly found that tactual perception of objects evoked a visual image, which was often followed by some spontaneous labelling or naming process.

The notion that early sensory training is a prerequisite for intellectual and social growth and the use of active exploration and manipulation of three dimensional material both have a long history in education (eg. Froebel, 1896; Montessori, 1912; Zaporozhets, 1965, 1969). A re-evaluation of the 'education of the senses' in terms of transfer of manipulative proficiency to other measurable skills may provide an external method of assessing the success of sensory training programs. Provided that an association exists between spatial aptitude, intramodal and cross modal functioning, and if effective haptic strategies can be identified and taught to children, spatial ability might be increased. However, only further research can determine whether a casual relationship exists between haptic proficiency and spatial skills and if instructional interventions designed to increase haptic ability will indeed result in a concomitant improvement in spatial skills.

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Table 1

SUMMARY OF EXPERIMENTAL CONDITIONS

Condition	Modality of Standard	Modality of Comparison	Method of Presentation: Simultaneous	Method of Presentation: Successive	Exploratory Hand(s)
1. H-H	Haptic	Haptic	X		R and L
2. H-H	Haptic	Haptic		X	R
3. H-H	Haptic	Haptic		X	L
4. V-H	Visual	Haptic		X	R
5. H-V	Haptic	Visual		X	R
6a. V-H	Visual	Haptic	X		R
b. H-V	Haptic	Visual	X		R

Table 2

MEAN ACCURACY AND HAPTIC SCORES FOR KINDERGARTEN, GRADE ONE AND GRADE TWO CHILDREN

GRADE	ACCURACY SCORE						HAPTIC SCORE					
	Condition[a]						Condition[a]					
	1	2	3	4	5	6	1	2	3	4	5	6
Kindergarten N = 20												
M	19.80	18.10	19.40	19.20	18.00	22.35	62.55	59.55	54.20	62.05	67.65	71.05
S.D.	3.11	3.02	2.06	2.95	3.26	3.08	17.87	21.76	18.25	17.93	21.61	17.15
Grade 1 N = 22												
M	20.82	18.68	20.95	20.27	19.64	22.95	64.82	68.14	67.95	73.64	74.59	79.14
S.D.	2.72	3.24	2.19	3.18	3.67	2.65	11.25	14.41	10.86	8.32	10.50	8.58
Grade 2 N = 23												
M	21.17	20.00	21.87	21.65	20.57	24.04	66.83	70.83	66.35	73.78	82.10	83.57
S.D.	2.27	2.17	2.78	2.67	3.01	2.34	17.49	19.27	22.43	14.47	17.16	13.26

Note Maximum accuracy score in each condition equals 30
Maximum haptic score in each condition equals 120

[a] Condition 1 - haptic-haptic simultaneous
Condition 2 - haptic-haptic successive (right hand)
Condition 3 - haptic-haptic successive (left hand)
} intramodal

Condition 4 - visual-haptic successive
Condition 5 - haptic-visual successive
Condition 6 - cross modal simultaneous
} intermodal

Table 3

ACCURACY SCORES AT THREE CRITERION LEVELS

Grade	Criterion Levels[a]		
	25%	50%	75%
Kindergarten	100	86	7
Grade 1	100	95	22
Grade 2	100	99	33

Note: In a paired-comparison task a 50% criterion level reflects chance responding.

[a]A criterion level of 25% denotes an accuracy score of at least 8 items judged correctly.
A criterion level of 50% denotes an accuracy score of at least 15 items judged correctly.
A criterion level of 75% denotes an accuracy score of at least 23 items judged correctly.

Table 4

DIFFERENTIAL HAPTIC EXPLORATIONS FOR KINDERGARTEN, GRADE ONE AND GRADE TWO CHILDREN

Percentages[a]

	Level of Haptic Score			
	1	2	3	4
Kindergarten (N = 20)	26.30	48.95	19.93	4.83
Grade 1 (N = 22)	6.65	52.38	37.80	3.17
Grade 2 (N = 23)	13.7	41.58	38.1	6.62

[a]Percent of total number of haptic explorations within each of the four levels of the haptic perception scoring sheet.

Table 5

PRODUCT MOMENT CORRELATION COEFFICIENTS BETWEEN AGE,
SELECTED STANDARDIZED TESTS, ACCURACY AND HAPTIC PERCEPTION SCORES

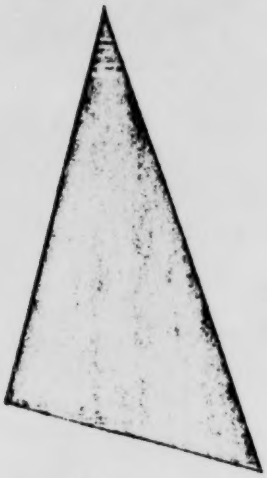
	1	2	3	4	5	6	7	8	9	10	11	12
1	--	.39	.67	.60	.58	.67	.52	.38	.40	.44	.26	.39
2		--	.46	.57	.47	.57	.46	.43	.32	.48	.35	.47
3			--	.69	.63	.71	.61	.31	.48	.59	.27	.33
4				--	.77	.83	.60	.43	.45	.60	.34	.46
5					--	.82	.63	.52	.54	.58	.47	.51
6						--	.66	.47	.57	.60	.42	.45
7							--	.68	.85	.91	.57	.65
8								--	.52	.58	.93	.95
9									--	.56	.52	.45
10										--	.50	.60
11											--	.77
12												--

CODE: 1 = Age; 2 = Ravens; 3 = Block Design; 4 = Gottschaldt Embedded Figures; 5 = Rutgers; 6 = Spatial Relations (PMA); 7 = Total Accuracy; 8 = Total Haptic Score; 9 = Accuracy for Conditions 1-3 (intramodal); 10 = Accuracy for Conditions 4-6 (intermodal); 11 = Haptic Score for Conditions 1-3; 12 = Haptic Score for Conditions 4-6.

Probability = $r = .25$ $p < .05$; $r = .32$ $p < .01$

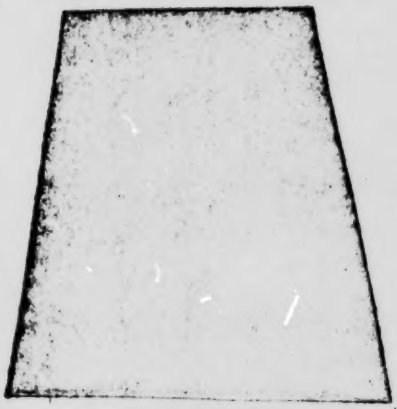
APPENDIX A

EUCLIDIAN RECTILINEAR SHAPES



E1

E2



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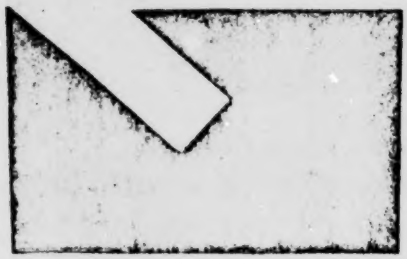
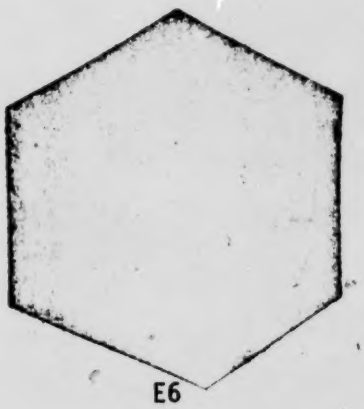
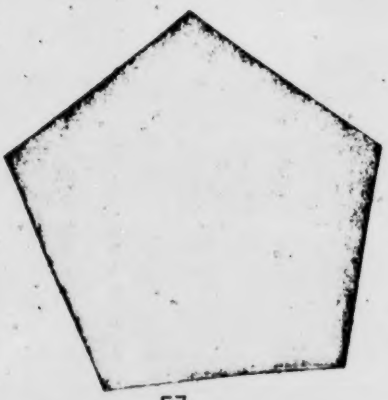


E4

E5



E6

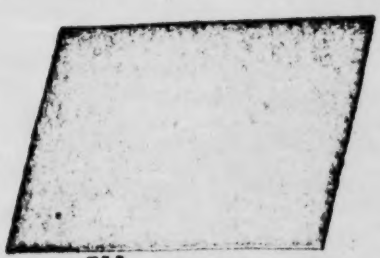


E7

E8

E9

E10



E11

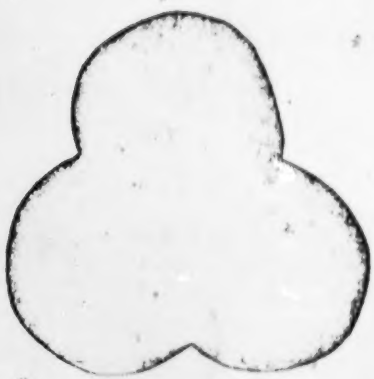
EUCLIDIAN CURVILINEAR SHAPES

E12

E13

E14

E15

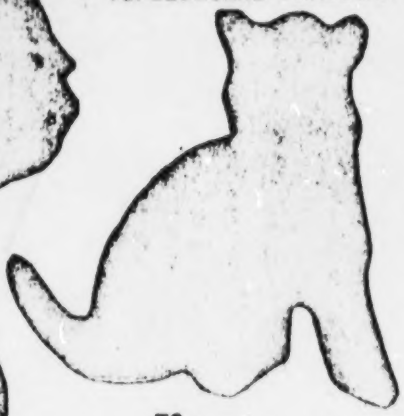


E16

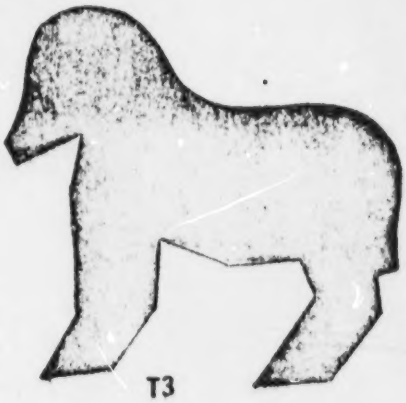
E17

TOPOLOGICAL FAMILIAR SHAPES

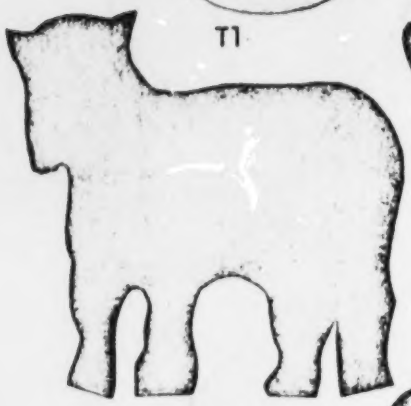
T1



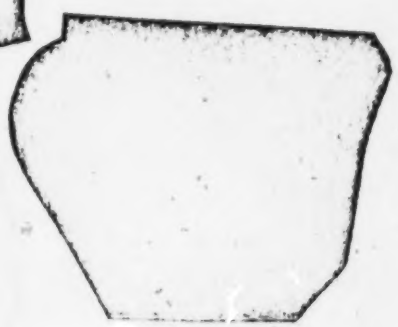
T2



T3

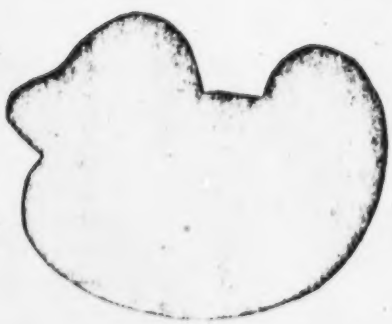


T4

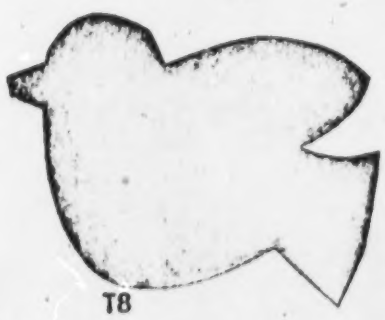


T5

T6

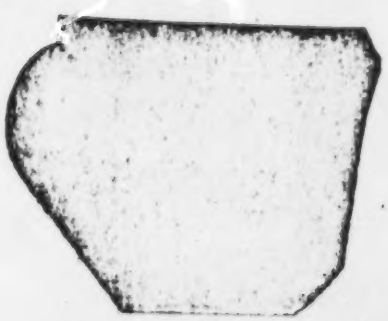


T7



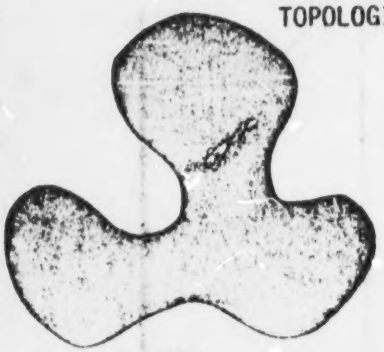
T8

T9



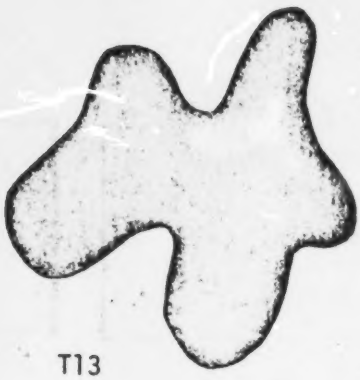
T10

TOPOLOGICAL UNFAMILIAR SHAPES

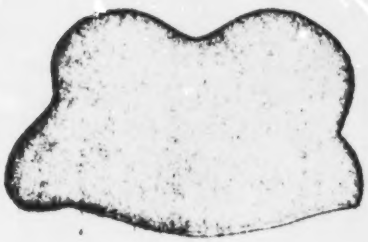


T11

T12



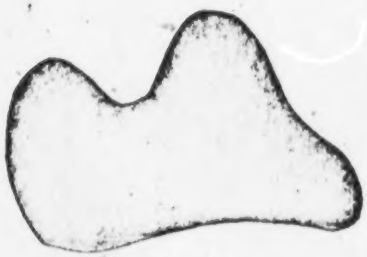
T13



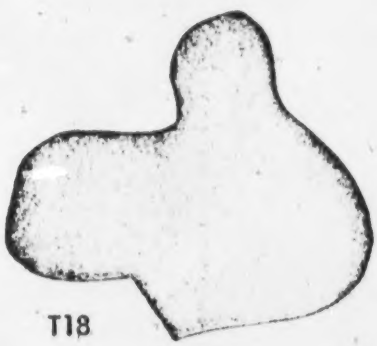
T14

T15

T16



T17



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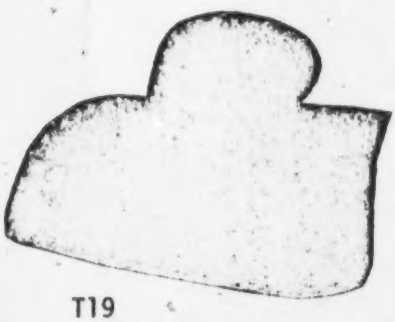


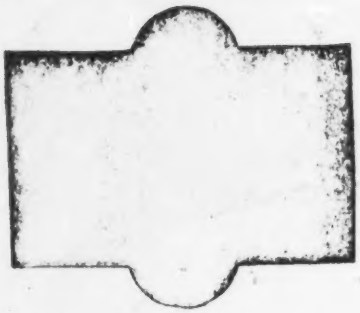
T19

MIXED SHAPES

M1

M2

M3

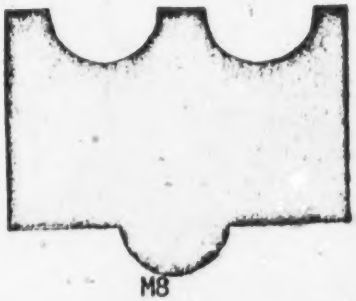


M4

M5

M6

M7



M8

M9

M10

M11

APPENDIX B

HAPTIC PERCEPTION SCORING SHEET

1. One point is given for minimal movements. The child is to demonstrate at least one of the following for each object manipulated:

   1) Putting hand on the outside surface of the object as if wearing mittens; such as holding a ball in fist (but not exploring the edges of object with palms of hands or surfaces of fingers).

   2) Feeling the surface of the edge with the palms of the hand (but not feeling the edges of object with the palm or active finger motions).

   3) Discovering a special characteristic of an object by chance, such as a handle or a hole in a topological form (but not actively searching for specific clues).

   4) Grasping object and turning it round and round (but not feeling the edges).

   5) Touching across diameter of object.

2. Two points are given for minimal, global and haphazard explorations of the object. The child must demonstrate at least one of the following for each object manipulated:

   1) Exploring haphazardly the edges of objects with the palms of hands and surfaces of fingers (but not systematically exploring the edges and specific features with the surfaces of fingers or finger tips).

   2) Taking hold of at least two extremities to establish a relationship between the two; such as grasping the points of a triangle with two hands (but not exploring the recessess of the edges).

3. Three points are given for active manipulation of the object with incomplete motions. The child must demonstrate at least one of the following for each object manipulated:

   1) Searching actively for significant clues of objects such as curves, straight lines and angles with incomplete motions (but not following through on the entire object or carefully examining specific clues).

   2) Turning the object over and over in one direction, feeling the edges simultaneously.

4. Four points are given for active acquaintance and manipulation. The child must demonstrate at least one of the following for each object manipulated:

   1) Carefully examining <u>all</u> specific clues; such as putting finger in and around edges of a hole.

   2) Locating extremities of objects and exploring recesses of edges; such as feeling both points and inner angles of a star.

   3) Exploring the whole contour or edges with one finger tip.

   4) Moving finger tips or surfaces of fingers around the edges and into the specific features.